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WATER QUALITY CONTROL STUDY NORWICH RESERVOIR NINNESCAH RIVER BASIN KANSAS

Federal Water Pollution Control Administration
Dallas, Texas

November 1966

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WATER QUALITY CONTROL STUDY
NORWICH RESERVOIR
NINNESCAH RIVER BASIN
KANSAS

Study of Needs and Value of Storage for Water Quality Control

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37

WATER QUALITY CONTROL STUDY

NORWICH RESERVOIR

NINNESCAH RIVER BASIN

KANSAS

Abstract

An investigation has been made to evaluate the need for and value of storage for water quality control purposes in the proposed Norwich Reservoir. Flows in the Arkansas River below Wichita, Kansas are not sufficient to assimilate present or anticipated future waste loads. Dilution flow releases from the project would, however, correct only the lower half of the polluted stretch of the Arkansas River.

Prepared for

U.S. DEPARTMENT OF THE INTERIOR

Bureau of Reclamation

Oklahoma City Development Office--Oklahoma

UNITED STATES DEPARTMENT OF THE INTERIOR
Federal Water Pollution Control Administration
South Central Region
Dallas, Texas

NOVEMBER 1966

TABLE OF CONTENTS

		Page
LIST OF TABLES		iii
LIST OF FIGURES		iii
I.	INTRODUCTION	
	Request and Authority	I-1
	Purpose and Scope	I-1
	Acknowledgments	I-1
II.	SUMMARY OF FINDINGS AND CONCLUSIONS	
	Summary of Findings	II-1
	Conclusions	II-1
III.	PROJECT DESCRIPTION	III-1
IV.	STUDY AREA DESCRIPTION	
	Location and Boundaries	IV-1
	Geography and Topography	IV-1
V.	WATER RESOURCES OF THE STUDY AREA	
	Quantity of Water Available	V-1
	Quality of Water Available	V-4
VI.	THE ECONOMY	VI-1
VII.	WATER QUALITY CONTROL	
	General	VII-1
	Water Quality Objectives	VII-1
	Municipal and Industrial Pollution	VII-2
	Flow Regulation	VII-2
VIII.	BENEFITS	
	Water Quality Control Storage Benefits	VIII-1

TABLE OF CONTENTS (Continued)

		Page
IX.	BIBLIOGRAPHY.	IX-1
	APPENDIX.	1

LIST OF TABLES

Number	Title	Page
III-1	Principal Features - Norwich Reservoir.	III-1
V-1	Natural Streamflow in the Arkansas River at Wichita.	V-1
V-2	Unit Runoff Values, Uncontrolled Area between Wichita and Arkansas City	V-2
V-3	Monthly Distribution of Uncontrolled Runoff Arkansas River at Wichita	V-2
V-4	Unregulated Flow at Norwich Dam	V-3
V-5	Monthly Distribution of Unregulated Flow at Norwich Dam.	V-4
V-6	Chemical Analysis of Streamflow	V-5

LIST OF FIGURES

Number	Title	Following Page
III-1	Location Map.	IX-1
VII-1	Dissolved Oxygen Profiles - 2020, Arkansas River, Wichita to Kaw Reservoir	VII-2
VII-2	Dissolved Oxygen Profiles - 2070, Arkansas River, Wichita to Kaw Reservoir	VII-2
VIII-1	Nitrogen Cycle.	VIII-2

I. INTRODUCTION

Request and Authority

In a letter dated July 2, 1965, the Oklahoma City Development Office of the Bureau of Reclamation requested the Public Health Service* to investigate and prepare a report on the need for and value of storage for water quality control purposes in Norwich Reservoir.

This study has been made in accordance with the Federal Water Pollution Control Act, as amended, (33 U.S.C. 466 et seq.).

Purpose and Scope

This study was made to examine the probable effects of the proposed project on water quality in the Arkansas River; to determine the benefits or harm resulting from changes in water quality; to evaluate the suitability of the water for proposed water quality uses; and, to determine the need for and the value of storage for regulation of streamflow for the purpose of water quality control. The study streams are the Ninnescah River, and that part of the Arkansas River from the city of Wichita, Kansas to Kaw Reservoir. The need for streamflow regulation was studied for present conditions and anticipated future conditions to the year 2070.

Acknowledgments

The cooperation of many individuals is gratefully acknowledged. Special appreciation is expressed to the following:

Bureau of Reclamation, Oklahoma City, Oklahoma
Kansas State Department of Health, Topeka, Kansas
City of Wichita, Kansas

*In accordance with the Water Quality Act of 1965 (Public Law 89-234), approved October 2, 1965, the Federal Water Pollution Control Act, as amended (33 U.S.C. 466 et. seq.) is now administered through the Federal Water Pollution Control Administration.

II. SUMMARY OF FINDINGS AND CONCLUSIONS

Summary of Findings

1. The Bureau of Reclamation, Oklahoma City, Oklahoma, is conducting a feasibility study of Norwich Reservoir on the South Fork of the Ninnescah River, a tributary to the Arkansas River in south-central Kansas.

2. The study area, comprising parts of six counties, consists of the Ninnescah River basin and that part of the Arkansas River basin from the city of Wichita, Kansas to Kaw Reservoir.

3. The principal waste producer in the study area is the city of Wichita which had a metropolitan area population of 343,000 in 1960. Wichita presently discharges 30 million gallons per day (mgd) having a population equivalent of about 75,000.

4. Surface water in the portion of the Arkansas River studied is of marginal quality, primarily because of upstream natural salt sources, with maximum and weighted average total dissolved solids of 1,680 and 617, respectively. Water quality is likewise marginal in the South Fork of the Ninnescah River because of the leaching of salt by ground water which subsequently enters the river by seepage. The maximum total dissolved solids concentration in the South Fork near the proposed reservoir site was 1,132 milligrams per liter (mg/l) while the average concentration was 481 mg/l.

Conclusions

1. The population of the Wichita metropolitan area is expected to increase to about 1,400,000 in 2020, and 2,965,000 in 2070.

2. Wichita's sewage effluent, which is discharged to the Arkansas River some 35 miles upstream from the confluence of the Ninnescah River, presently reduces the dissolved oxygen concentration below 4 mg/l.

3. The effectiveness of releases from Norwich Reservoir for water quality control is restricted because of the geographical location of the dam. Releases from the project for this purpose would enter the Arkansas River downstream from the point where the quality of the river is initially reduced below acceptable dissolved oxygen limits, and, therefore, would correct only about one-half of the polluted stretch of the Arkansas River.

4. Several alternative methods to provide acceptable dissolved oxygen concentrations in the entire reach of the Arkansas River studied were considered. These methods were:

   (a) Transporting dilution water from the project to the point in the Arkansas River where the dissolved oxygen concentration is initially reduced below 4 mg/l.

   (b) Application of advanced waste treatment methods to Wichita's waste flow to provide a higher degree of first-stage biochemical oxygen demand (BOD) removal.

   (c) Piping that portion of Wichita's treated sewage that exceeds the assimilative capacity of the Arkansas River downstream to the confluence of the Ninnescah River and the Arkansas River where it would be diluted with water quality control releases from Norwich Reservoir.

5. The dilution flow required to maintain acceptable dissolved oxygen concentrations in the Arkansas River between Wichita, Kansas and Kaw Reservoir is about 900 acre-feet per year in 1960, 24,000 acre-feet per year by 2020, and 125,000 acre-feet per year by 2070. The yield of Norwich Reservoir, 58.6 mgd or 65,600 acre-feet per year, if conveyed to the Arkansas River as suggested above, would satisfy these needs until about 2045.

6. The value of benefits attributable to provision of storage to provide 58.6 mgd from Norwich Reservoir for water quality control, as determined by the cost of the most likely alternative to the project, amounts to $704,000 annually. Since storage needs are based on a system that would provide acceptable dissolved oxygen concentrations in the entire reach of the Arkansas River studied, the cost of a single-purpose reservoir at the project site that would provide a yield of 58.6 mgd has been reduced by the cost of transporting the dilution flow from the project to the point of need on the Arkansas River.

III. PROJECT DESCRIPTION

The proposed Norwich Reservoir would be located on the South Fork of the Ninnescah River, about 70 river miles from the Arkansas River in south-central Kansas. (See the location map, figure III-1 following page IX-1.)

Principal features of the reservoir are shown in table III-1.

Table III-1

Principal Features - Norwich Reservoir

Drainage Area, square miles

Normally contribution	546
Contributing during intense storms	560

	Elevation (ft., m.s.l.)	Capacity (acre-feet)	Area (acres)
Surcharge	1,460.0	143,181	12,750
Flood Control	1,447.5	68,000	10,108
Conservation	1,440.0	142,234	7,908
Inactive	1,403.4	4,031	1,075
Dead	1,399.0	4,682	754
Streambed	1,376.0	0	0

Dependable Yield, mgd 58.6

Source: Bureau of Reclamation [1/]

IV. STUDY AREA DESCRIPTION

Location and Boundaries

The study area, comprising parts of six Kansas counties, consists of the Ninnescah River basin and the Arkansas River basin between the city of Wichita, Kansas and Kaw Reservoir in south-central Kansas. General features of the basins are shown in figure III-1.

Geography and Topography

The upper reaches of the North and South Fork basins of the Ninnescah River are, generally, flat, undulating plains with stream patterns relatively undefined. In the lower reaches of the North and South Forks and along the main stem of the Ninnescah, the channels are well defined in shallow valleys from one to three miles in width. The topography of the basin as a whole is relatively flat to slightly rolling. Much of the basin is covered with a sandy soil which is easily eroded by both wind and water.

The portion of the Arkansas River basin studied is largely an undulating plain of slight relief. Much of the area is covered with sandy soils. The Arkansas River has a broad, sandy bed which averages about 400 feet in width, with low banks six to eight feet high.

The study area has a humid to moist, subhumid climate with an average annual precipitation varying from about 22 to 33 inches, increasing in an easterly direction.

The annual mean temperature of the area is about 57°F, with monthly mean temperatures varying from 32°F in January to 81°F in July.

The State's largest city, Wichita, with a 1960 population of almost 225,000, is located in the eastern portion of the study area.

V. WATER RESOURCES OF THE STUDY AREA

Quantity of Water Available

Dependable Uncontrolled Runoff

The quantity of uncontrolled runoff in the study streams was determined from period-of-record data at three gaging stations, Arkansas River at Wichita*, Arkansas River at Arkansas City, and Ninnescah River at Peck. 2-4/

Natural streamflow in the Arkansas River at Wichita at various exceedence frequencies are listed in table V-1. Unit runoff values, i.e., cubic feet per second per square mile (cfs/sq.mi.), were determined for the study area by subtracting the flow in the Arkansas River at Wichita and in the Ninnescah River at Peck from that in the Arkansas River at Arkansas City and distributing this amount over the incremental drainage area. In this manner, the annual average unit runoff was determined for various exceedence frequencies, as shown in table V-2. The drainage areas of the uncontrolled runoff in the study area are as follows: Arkansas River from Wichita to the confluence with the Ninnescah River, 2,512 square miles; Arkansas River from the confluence with the Ninnescah River to the tailwaters of Kaw Reservoir, 437 square miles; and below Cheney and Norwich Reservoirs to the confluence of the Ninnescah River, 706 square miles.

Table V-1

Natural Streamflow in the Arkansas River at Wichita

Exceedence Frequency (%)	Annual Average Flow (cfs)
98	195
95	220
90	250
80	325
50	830

* Data prior to April 1935 was adjusted to account for a change in the location of the gaging station.

Table V-2

Unit Runoff Values
Uncontrolled Area Between Wichita and Arkansas City

Exceedence Frequency (%)	Annual Average Unit Runoff (cfs/sq.mi.)
98	0.014
95	0.023
90	0.034
80	0.055
50	0.129

Median monthly runoff for the period-of-record was expressed as a percentage of the yearly total and applied to the annual value in evaluating monthly runoff values. Table V-3 shows the monthly variation of the streamflow in the Arkansas River at Wichita and the uncontrolled runoff in the study area.

Table V-3

Monthly Distribution of Uncontrolled Runoff
Arkansas River at Wichita

Month	% of Annual Average Flow	Month	% of Annual Average Flow
January	65	July	166
February	83	August	94
March	89	September	77
April	83	October	77
May	168	November	61
June	179	December	60

Dependable Controlled Flow

The following pertinent design data defines, in a measure, the character of the study reservoir: mean annual inflow, 126,500 acre-feet; conservation storage, 142,234 acre-feet; average annual evaporation, 19,500 acre-feet; and annual dependable yield, 65,600 acre-feet. A dependable controlled flow of 5 cubic feet per second (cfs) will exist because of seepage through Norwich Dam. 1/

Cheney Reservoir, located on the North Fork of the Ninnescah River, was constructed in 1964 by the Bureau of Reclamation. The dam controls 901 square miles of drainage area. The reservoir has a controlled storage capacity of 243,300 acre-feet, of which 80,900

acre-feet are allocated for flood control, 149,500 acre-feet for irrigation and water supply, and 12,900 acre-feet for sediment reserve. It is estimated that seepage from Cheney to the stream channel below the dam would average 5 cfs.

Based on a firm yield operation study of the reservoir furnished by the Bureau of Reclamation, releases from Cheney are not anticipated during low flow conditions. The city of Wichita uses water from the reservoir for their water supply and has constructed a pipeline to their treatment plant with a design capacity of 60 mgd. At the present time it is not known how Wichita plans to operate Cheney Reservoir.

Unregulated Flow at the Project Damsite

Based on period-of-record data for the gaging station on the Ninnescah River near Peck, Kansas, the annual average flow at various exceedence frequencies, described in table V-4, would be available from the project controlled drainage area without regulation.

Table V-4

Unregulated Flow at Norwich Dam

Exceedence Frequency (%)	Annual Average Flow (cfs)
98	30.6
95	38.5
90	47.4
80	60.3
50	94.8

A monthly distribution of the unregulated flow at Norwich Dam is given in table V-5.

Table V-5

Monthly Distribution of Unregulated Flow at Norwich Dam

Month	% of Annual Average Flow	Month	% of Annual Average Flow
January	79	July	102
February	96	August	48
March	124	September	50
April	134	October	70
May	182	November	73
June	166	December	76

Quality of Water Available

The chemical quality of surface water in the study area is shown in table V-6. The sampling stations are located on the South Fork of the Ninnescah River near Murdock, Kansas, approximately two miles downstream from the proposed damsite, and on the Arkansas River at Arkansas City, some 26 miles downstream from the mouth of the Ninnescah River.

Maximum, minimum, and weighted average values are given for total dissolved solids, sulfates, and chlorides for the period of record at each station. Discharge values were not measured in some cases, therefore, these data could not be used in computing weighted average values. For natural streamflow at low flow conditions, total dissolved solids (TDS) concentration would be higher than the arithmetic mean since TDS values increase with lower flows.

Surface water in the stretch of the Arkansas River studied is of marginal quality because of upstream natural salt sources, with maximum and weighted average total dissolved solids of 1,680 mg/l and 617 mg/l, respectively. Streamflow in the South Fork of the Ninnescah River is likewise marginal because of the leaching of salt by ground water in the 8-mile stretch, from a mile west of Cairo to north of Cunningham (see Location Map), which subsequently enters the river by seepage. 8/ The maximum total dissolved solids concentration in the South Fork at Murdock was 1,132 mg/l while the average concentration was 481 mg/l.

Table V-6

Chemical Analysis of Streamflow

Location of Sampling Station	Total Dissolved Solids	Sulfates	Chlorides
South Fork of the Ninnescah a/ River at Murdock, Kansas			
Weighted Average	481	29	155
Maximum	1,132	70	500
Minimum	124	9.5	22
Arkansas River at Arkansas City b/			
Weighted Average	617	111	190
Maximum	1,680	306	680
Minimum	140	27	28
Recommended Upper Limit of Public Health Service Drinking Water Standards, 1962	500	250	250

a/ Continuous sampling from September 1, 1950 through September 30, 1951; grab samples from November 14, 1956 through September 10, 1963 (84 samples - 61 with corresponding discharge values). 5-7/

b/ Continuous sampling from October 1, 1960 through September 30, 1963. 7,8/

VI. THE ECONOMY

The economics section serves as a basis for estimating future municipal and industrial water use with resulting waste discharge. The waste flows pertinent to this investigation are based on those developed in a recent study by the Federal Water Pollution Control Administration pertaining to Kaw Reservoir. 9/

From the Kaw Reservoir study, the population of the Wichita metropolitan area is expected to increase from 343,000 in 1960 to about 1,400,000 in 2020, and 2,965,000 in 2070. In 1960, the reported municipal water use for the city of Wichita was almost 30 mgd. Fucure municipal and industrial water requirements for the Wichita metropolitan area are projected to be approximately 330 mgd in 2020, and 620 mgd by 2070.

VII. WATER QUALITY CONTROL

General

Water quality control is defined as any measure employed to enhance the utility, value, and attractiveness of waters used for purposes which are affected by changes in water quality. The use of water by man in his many activities and the subsequent return of waste effluent even after secondary treatment, causes some degradation of water quality. As population and the associated water demand increases, the problem caused by waste water becomes more significant. If the quality of the stream receiving this treated waste is reduced below acceptable limits, additional water of better quality is necessary to correct this condition. This report is concerned with the effects of releases from Norwich Reservoir on water quality in the Ninnescah and Arkansas Rivers.

Water Quality Objectives

Of the indicators presently available as measures of water quality, dissolved oxygen and total dissolved solids were selected as the water quality objectives of this study. Dissolved oxygen is used to measure the effect of organic pollutants (those constituents which will, with time, decompose in the stream), as appraised by biochemical oxygen demand (BOD).* Dissolved oxygen is a significant factor in maintaining an environment for propagation of fish and other aquatic life. A lower limit of 4 mg/l of dissolved oxygen was used since (1) it provides an acceptable environment for most aquatic life native to this area, and (2) it provides a buffer zone in the event unforeseen spills of waste occur.

Dissolved solids are employed to characterize the effects of stable pollutants (those constituents which are not utilized or reduced by the stream environment), such as chloride and sulfate salts. The discharge weighted average of total dissolved solids in the South Fork of the Ninnescah near the proposed reservoir site is 481 mg/l and in the reach of the Arkansas River under study is 617 mg/l, as described in Chapter V. Therefore, dilution releases from the project for this purpose would have only a small effect on the quality of the Arkansas River.

Since there are no existing or anticipated municipal and/or industrial users of water from the stretch of the Arkansas River studied, consideration of storage for water quality control purposes is based on fish and wildlife, recreation, and aesthetic value.

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*Future water quality control requirements are based on the provision of sufficient treatment of waste flow to remove 90 percent of the first stage BOD.

Municipal and Industrial Pollution

Stream Loading

To evaluate the quality of the Arkansas River at the mouth of the Ninnescah River, pollution entering the river upstream from this point must be determined. Therefore, present and projected return flows for the city of Wichita, some 35 miles upstream from the project river were needed. The projected quantity and quality of municipal and industrial return flows presented in the water supply and water quality control study on Kaw Reservoir conducted by the Federal Water Pollution Control Administration 9/ are used as a basis for analysis on this study.

The projected quantity of municipal and industrial return flows was estimated to be 67 percent of the water used for this purpose. Future return flow from industrial cooling operations was considered to be 50 percent of the water used for this purpose.

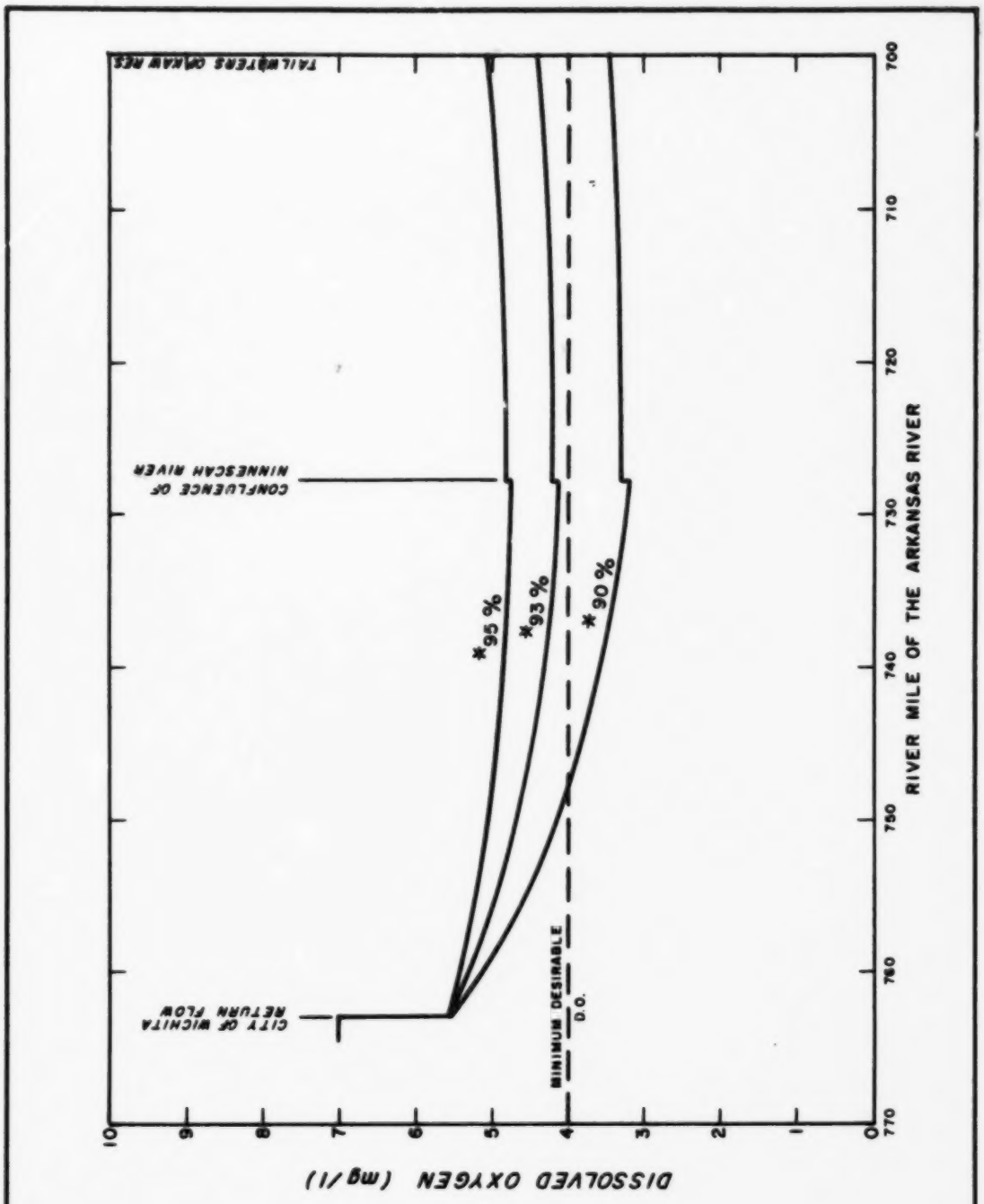
The municipal and industrial waste flow of Wichita was estimated to have an untreated, ultimate first-stage BOD concentration of 300 mg/l.

At the present time (1960), the average return flow of Wichita is 30 mgd with a population (P.E.) of 75,000. 10/ The return flow is expected to increase to 209 mgd in 2020 (P.E. of 181,900, and to 414 mgd in 2070 (P.E. of 380,900) after adequate treatment.

Flow Regulation

In investigating the organic pollution of the receiving streams, electronic computational methods were used. Monthly dissolved oxygen concentrations were determined in the reach of the Arkansas River from Wichita to the Kaw Reservoir for present (1960), 2020, and 2070 conditions. This analysis utilized low natural streamflow and runoff values, based on a 95 percent recurrence interval. These data were developed from gaging stations on the Arkansas River at Wichita, Kansas, and Arkansas City, Kansas, and the Ninnescah River near Peck, Kansas. (See Chapter V of this report.) It is concluded that municipal and industrial treated waste flow from Wichita that is discharged to the Arkansas River, at river mile 763, reduces the dissolved oxygen concentration of the river to undesirable levels.

In the summer months dissolved oxygen concentrations in the Arkansas River fall below 4 mg/l (see figures VII-1 and VII-2) downstream from Wichita and reach a minimum value at the mouth of the Ninnescah River. Natural runoff of the Ninnescah River watershed raises the dissolved oxygen concentration in the Arkansas River. At this point the river begins to recover, although it does not reach acceptable conditions by the time it enters Kaw Reservoir.



NOTE

Projected 2020 condition for most severe month.

*Treatment of the City of Wichita's sewage effluent to various percentages of B.O.D. removed.

WATER QUALITY CONTROL STUDY
NORWICH RESERVOIR
NINNESCAH RIVER BASIN – KANSAS

DISSOLVED OXYGEN PROFILES – 2020
ARKANSAS RIV. – WICHITA TO KAW RES.

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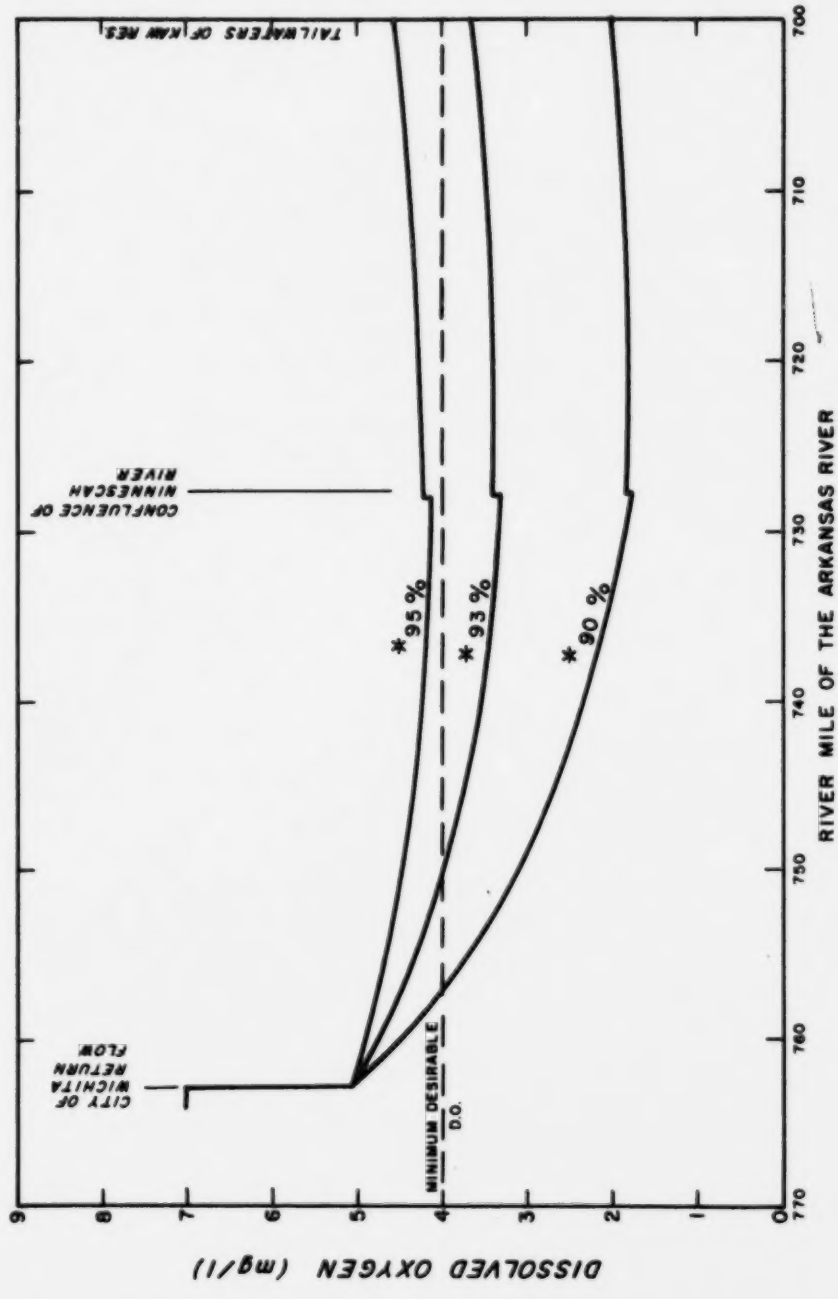
FIGURE VII-1



NOTE

Projected 2070 condition for most severe month.

*Treatment of the City of Wichita's sewage effluent to various percentages of B.O.D. removed.

WATER QUALITY CONTROL STUDY
NORWICH RESERVOIR
NINNESCAH RIVER BASIN – KANSAS

DISSOLVED OXYGEN PROFILES – 2070
ARKANSAS RIV.-WICHITA TO KAW RES.

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FIGURE VII-2

Releases from proposed Norwich Reservoir for water quality control would enter the Arkansas River downstream from the point where the organic quality of the river is initially reduced below acceptable limits. Therefore, only a portion of the polluted stretch of the river would be corrected by gravity-flow releases from the reservoir.

The following draft-on-storage* would provide 4 mg/l of dissolved oxygen in the reach of the Arkansas River between the Ninnescah River and Kaw Reservoir, a distance of 28 miles: 900 acre-feet per year in 1960, 24,000 acre-feet annually in 2020, and 125,000 acre-feet annually in 2070. Seepage loss from Cheney Reservoir, 5 cfs (3,620 acre-feet per year) would satisfy water quality control requirements until about 1980, and seepage loss from Norwich, 5 cfs (3,620 acre-feet per year), would meet these needs until the year 1985. These seepage losses are not assured quantities but are values determined by the construction agency and have a high probability of occurrence. The yield of the study reservoir, 58.6 mgd (65,500 acre-feet/year), would be sufficient to meet the above requirement until about 2045.

*Annual draft-on-storage is the sum of the incremental excesses of needed releases over inflows during a climatic year.

VIII. BENEFITS

Water Quality Control Storage Benefits

The benefits attributable to storage in Federal reservoirs for water quality control are defined as the net contribution to public health, safety, economy, and effectiveness in use and enjoyment of water for all purposes which are subject to detriment or betterment by virtue of change in water quality. Senate Document No. 97 states:

> "The net contribution may be evaluated in terms of avoidance of adverse effects which would accrue in the absence of water quality control, including such damages and restrictions as preclusion of economic activities, corrosion of fixed and floating plant, loss or downgrading of recreational opportunities, increased municipal and industrial water treatment costs, loss of industrial and agricultural production, impairment of health and welfare, damage to fish and wildlife, siltation, salinity intrusion, and degradation of the esthetics of enjoyment of unpolluted surface waters, or, conversely, in terms of the advantageous effects of water quality control with respect to such items. Effects such as these may be composited roughly into tangible and intangible categories, and used to evaluate water quality control activities. In situations where no adequate means can be devised to evaluate directly the economic effects of water quality improvement, the cost of achieving the same results by the most likely alternative may be used as an approximation of value."

Several alternative methods to provide acceptable dissolved oxygen conditions in the entire reach of the river studied were considered and are explained below. Estimated cost analyses for each of the alternatives are presented in the Appendix to this report. In evaluating the benefits, the period of study was to the year 2070 (100 years), and a 3 1/8 percent interest rate was used. Construction facilities in all plans were considered to be structurally capable of a 100-year life, with periodic minor repair as needed (included in the annual operation and maintenance charge). The cost of replacing mechanically operated equipment, such as pumps, motors, and chemical-feed devices, is likewise included in the annual operation and maintenance charge.

Transporting water quality control releases from the reservoir to the point in the Arkansas River where the dissolved oxygen concentration is initially reduced below acceptable conditions would correct the entire stretch of the river studied. This plan could be implemented by either a pressure- or gravity-flow system. The pressure

system would require releasing the stored water to a diversion dam at about river mile 30 on the Ninnescah River and then pumping this flow through a pipeline to the point of need on the Arkansas River, at about river mile 757. The pipeline would be approximately nine and one-half miles in distance with a static head of 70 feet. The gravity system could be used if the reservoir releases were diverted just below the confluence of the North and South Forks of the Ninnescah River. An open channel generally following the contour of the land could be used for the 24 mile route which has an elevation differential of some 50 feet.

The application of advanced waste treatment methods to Wichita's sewage to remove more of the first-stage BOD load was also investigated. Figures VII-1 and VII-2 illustrate the effect of the degree of BOD removal on the dissolved oxygen concentration in the reach of the Arkansas River studied. Dissolved oxygen profiles for various percentages of treatment (90, 93, and 95) were plotted for the most severe condition (July) in 2020 and 2070. To maintain a minimum dissolved oxygen concentration of 4 mg/l, sufficient waste treatment must be provided to remove 92.5 percent of the BOD in 2020, and 94.5 percent in 2070. A foam separation plant would remove 93 percent of the first-stage BOD while a lime-alum coagulation and sedimentation, plus adsorption plant, would remove 96 percent of the BOD.

The method stated above does not appear to be a true alternative to storage for dilution flow, however, since it does not achieve the same results. Although the first-stage BOD of a sewage can be reduced to maintain acceptable dissolved oxygen levels in the stream, an additional oxygen demand is exerted as a result of (a) second-stage BOD in the organic waste matter, and (b) the decay of algae that utilize nutrients for food.

To explain further, the oxygen demand on a stream is exerted by two classes of materials: carbonaceous organic material (first-stage BOD), and oxidizable nitrogen (second-stage BOD), which occurs primarily as free ammonia nitrogen and organic nitrogen. The second-stage BOD is exerted when oxidizable nitrogen is oxidized to nitrites and then nitrates by bacterial decomposition of organic matter which, along with phosphates, can be used as food for algae. An additional secondary BOD results from the death and decomposition of these algae. As a result, nitrogen and phosphorus again become available for plant food. This cyclical effect, as shown in figure VIII-1, can occur several times in the reach of a stream.

As the first-stage BOD is reduced by treatment, dilution water needs are no longer determined by disposal of BOD but, rather, for disposing of nitrogen and phosphorus. Conventional advanced waste treatment methods currently considered for planning purposes will remove as high as 97 percent of the phosphate and 75 percent of the

WATER QUALITY CONTROL STUDY
NORWICH RESERVOIR
NINNESCAH RIVER BASIN — KANSAS

NITROGEN CYCLE

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FIGURE VIII-1

nitrogen in wastes reaching the treatment plant. Streams receiving highly treated effluent tend to develop algal growths immediately below the point of discharge while those receiving poorly treated wastes will generally develop algal growths further downstream.

The upper level of permissible concentration of available nitrogen, if algal trouble is to be prevented, appears to be about 1.0 mg/l. In the Arkansas River at Arkansas City, the weighted average concentration of nitrates alone, exclusive of organic nitrogen, ammonia nitrogen, and nitrites, is over 5 mg/l. Even if it were possible to remove all of the nitrogen and phosphorus in the sewage waste, natural streamflow would contain sufficient nutrient concentrations to cause algae growth, which in time decay and exert a demand on the dissolved oxygen of the stream.

In a range somewhere near the 90 percent first-stage BOD removal lies a particular degree of treatment beyond which it is not practical to treat for organic conditions in the stream. This value is highly variable, depending on stream characteristics and environment, the unpredictable nitrogen cycle, and other sources of nutrient loads. Information to develop the optimum treatment of waste flow for BOD removal is limited. It is questionable that the assimilative capacity of the stream, as effected by the nutrients, would be sufficient to maintain dissolved oxygen concentrations above acceptable limits even with advanced waste treatment.

As another alternative, that portion of Wichita's treated sewage that exceeds the assimilative capacity of the Arkansas River could be piped downstream to the confluence of the Ninnescah River, where it would be diluted with water quality control releases from Norwich Reservoir. This plan would require a pipeline about 22 miles in distance with an elevation drop of approximately 100 feet.

A final alternative reviewed was the provision of storage for water quality control in a reservoir upstream from the city of Wichita. Dilution flow releases from the reservoir would be available at the point of original need on the Arkansas River to provide minimum dissolved oxygen concentrations of 4 mg/l in the entire reach studied. There are no such reservoirs, either existing, under construction, or planned, that would be of sufficient size and located close enough to the need area to be functional, i.e., so the released water would not be used for irrigation in the interim distance. Further consideration should be given to constructing a reservoir to be used singularly, with a yield, if possible, capable of meeting the 2070 needs, or in conjunction with the Norwich system to meet the 2070 demand.

A somewhat greater BOD load entering Kaw Reservoir results when the critical point of the oxygen sag is moved downstream and, thus closer to the reservoir by, to a greater extent, piping Wichita's sewage downstream and, to a lesser degree, providing dilution flow

above Wichita. These loads are not anticipated to be of sufficient magnitude to cause any significant problems with the normal dispersion and mixing characteristics expected in the reservoir. It is recommended, however, that further studies be made of the actual mixing conditions throughout Kaw Reservoir, either by dye or sampling methods, to more accurately evaluate the effect of Wichita's waste on the organic quality of the reservoir.

The cost of dilution water which would be used in the first three plans was based on a single-purpose reservoir at the proposed project site, since there are no alternate sites nearby. The capital cost was converted to an equivalent annual cost and added to the annual operation and maintenance cost. On this basis, storage in Norwich Reservoir for water quality control purposes, if it were located above Wichita, would have an annual value of $870,000.

Since gravity-flow releases from Norwich Reservoir for water quality control purposes would correct only about one-half of the polluted stretch of the Arkansas River, full benefit could not be given to storage for this purpose. To evaluate the actual benefits, the cost of the storage for dilution flow was reduced by the cost of the most economical system that would provide acceptable dissolved oxygen concentrations in the entire reach of the Arkansas River studied. In this case, the system was a gravity-flow channel that would transport the dilution flow from the project to the original point of need on the Arkansas River. Using this analysis, the benefits for storage in Norwich Reservoir for water quality control would have an annual value of $704,000.

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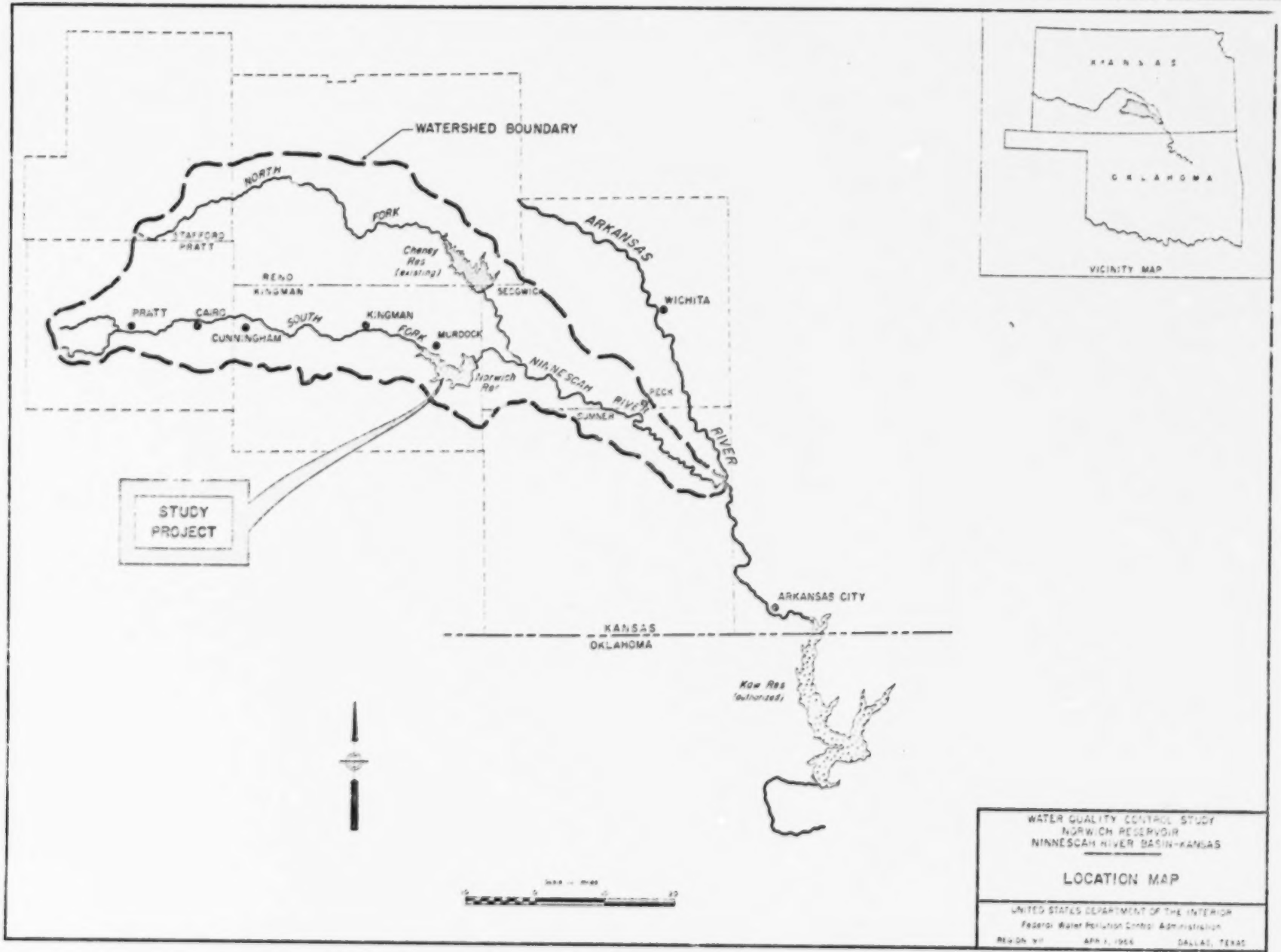
WATERSHED BOUNDARY
NORTH
FORK
ARKANSAS
STAFFORD
PRATT
Cheney Res (existing)
RENO
KINGMAN
SEDGWICK
WICHITA
PRATT
CAIRO
CUNNINGHAM
SOUTH
FORK
KINGMAN
MURDOCK
Norwich Res
NINNESCAH
RIVER
PECK
SUMNER
RIVER
STUDY PROJECT
ARKANSAS CITY
KANSAS
OKLAHOMA
Kaw Res (authorized)
KANSAS
OKLAHOMA
VICINITY MAP
WATER QUALITY CONTROL STUDY
NORWICH RESERVOIR
NINNESCAH RIVER BASIN-KANSAS
LOCATION MAP
UNITED STATES DEPARTMENT OF THE INTERIOR
Federal Water Pollution Control Administration
REGION VII APR 1, 1966 DALLAS, TEXAS
FIGURE III-1

APPENDIX

APPENDIX

Summary of Alternative Cost Computations for Water Quality Control Benefits

Plan 1 - Pumping dilution flow upstream to the point of initial need on the Arkansas River.

Design Data:

Discharge (cfs): maximum monthly

1970 - 50
1990 - 90
2020 - 235
2045 - 425
2070 - 425

Static head - 70 feet
Distance - 9.6 miles

1970 System: 90 cfs

First Cost:

60" R.C.P.	$3,015,600
1 pumping plant	719,800
Diversion dam	313,000
	$4,048,400

Annual Cost:

Amortize 100 years @ 3 1/8%	132,600
Annual power cost	22,500
Annual operation and maintenance	13,900
	$ 169,000

1990 System: 150 cfs additional

First Cost:

72" R.C.P.	$3,896,400
1 pumping plant	1,399,000
	$5,295,400

Annual Cost:

Amortize first cost	$ 173,500
Annual power cost	31,400
Annual operation and maintenance	21,600
	$ 226,500

Capitalized cost for 80 years $6,629,900

Discount 20 years (1990-1970)	$3,580,100
Amortize 100 years @ 3 1/8%	117,300

2020 System: 185 cfs additional

First Cost:

84" R.C.P.	$5,132,400
1 pumping plant	1,955,600
	$7,088,000

Annual Cost:

Amortize first cost	$ 232,000
Power cost	34,600
Operation and maintenance	29,200
	$ 295,800
Capitalized cost for 50 years	$7,438,500
Discount 50 years	1,599,300
Amortize 100 years @ 3 1/8%	52,400
Annual Cost of Plan 1	$ 338,700
Say	339,000
Annual cost of a single-purpose Reservoir at the project site	$ 870,000
Total Annual Cost	$1,206,000

Plan 2 - Transporting dilution flow by open channel to the point of initial need on the Arkansas River

Design Data:

Distance - 24 miles
Slope - 50' elevation difference or 0.38'/100'
Discharge - Design for 2045 maximum monthly flow - 420 cfs

Channel Design: 8' height with an 11' bottom width; 1.5:1 side slopes, plastic lined.

First Cost:

R.O.W.	$ 280,000
Diversion dam	250,000
Excavation & fill	2,351,500
Plastic lining (includes replacement every 20 years)	783,900
Engineering & contingencies	846,000
	$4,511,400

Annual Cost:

Amortize first cost for 100 years @ 3 1/8%	147,800
Operation & Maintenance	
Diversion dam	7,800
Channel Maintenance	10,000
Annual Cost of Plan 2	$ 165,600
Say	166,000
Annual cost of a single-purpose reservoir at the project site	$ 870,000
Total Annual Cost	$1,033,000

Plan 3 - Advanced Waste Treatment Methods

Treatment to remove more than conventional 90 percent BOD presently needed. Ninety-three percent BOD removal would maintain acceptable DO in receiving stream until 2030. By 2070, 94.5 percent BOD removal required.

Return Flow

1970 - 58 mgd
2000 - 140 mgd
2030 - 240 mgd
2045 - 300 mgd
2070 - 415 mgd

1970 System: 80 mgd foam separation plant

First Cost:	$2,400,000
Annual Cost:	
Amortize first cost for 100 years @ 3 1/8%	$ 79,000
Operating cost (average)	87,000
	$ 166,000

2000 System: additional 160 mgd foam separation plant

First Cost:	$4,800,000
Annual Cost:	
Amortize first cost	$ 157,000
Operating cost (average)	113,000
	$ 270,000
Capitalized cost for 70 years	$7,637,000
Discount 30 years to 1970	$3,032,000
Amortize 100 years @ 3 1/8%	99,000

2030 System: additional 37 mgd coagulation-sedimentation plant (93%) + adsorption plant (99%)

First Cost	$8,140,000
Annual Cost	
Amortized first cost	$ 267,000
Operating cost (average)	317,000
	$ 584,000
Capitalized cost for 40 years	$13,237,000
Discount 60 years	$2,091,000
Amortize 100 years @ 3 1/8%	68,500
Total Annual Cost of Plan 3	$ 334,000

Plan 4 - Piping Wichita's treated effluent downstream to the confluence of the Arkansas River and the Ninnescah River.

Design Data:

Distance - 22 miles
Elevation Drop - 100 feet

1970 System: 120 mgd or 190 cfs

First Cost:

17 miles of 2-76" R.C.P. in place	$9,659,800
5 miles of 2-66" R.C.P. in place	2,415,900
	$12,075,700

Annual Cost:

Amortize first cost (100 years @ 3 1/8%)	$ 395,600
Operation and Maintenance	6,600
	$ 402,200

2000 System: additional 80 mgd or 125 cfs

First Cost:

17 miles of 1-90" R.C.P. in place	$7,905,000
5 miles of 1-78 R.C.P. in place	1,875,000
	$9,780,000

Annual Cost:

Amortize first cost (100 years @ 3 1/8%)	$ 320,400
Operation and manitenance	5,500
	$ 325,900

Capitalized cost in 2000 for 70 years	$9,218,700
Discount 30 years to 1970	$3,659,800
Amortize 100 years @ 3 1/8%	$ 119,900

2030 System: additional 155 mgd or 240 cfs

First Cost:

17 miles of 2-85" R.C.P. in place	$12,724,100
5 miles of 2-72" R.C.P. in place	2,841,100
	$15,565,200

Annual Cost:

Amortize first cost (100 years @ 3 1/8%)	$ 509,900
Operation and Maintenance	11,000
	$ 520,900
Capitalized cost in 2030 for 40 years	$11,801,000
Discount 60 years to 1970	$1,864,600
Amortize 100 years @ 3 1/8%	$ 61,100
Total Annual Cost of Plan 4	$ 583,200
Say	$ 583,000
Annual cost of a single-purpose reservoir at the project site	$ 870,000
Total Annual Cost	$1,450,000

Single-purpose reservoir at the proposed project site (58.6 mgd yield)

First Cost*	$23,000,000
Construction Cost*	1,797,000
	$24,797,000

Annual Costs:

Amortize first cost for 100 years @ 3 1/8%	812,300
Operation, maintenance and major replacement*	57,300
Total	$ 869,600
Say	$ 870,000

*Determined by the Federal Water Pollution Control Administration.